

Ecosystem modelling with Ecopath with Ecosim

An introduction

Dr Jesse van der Grient
Senior quantitative marine ecologist

Objectives

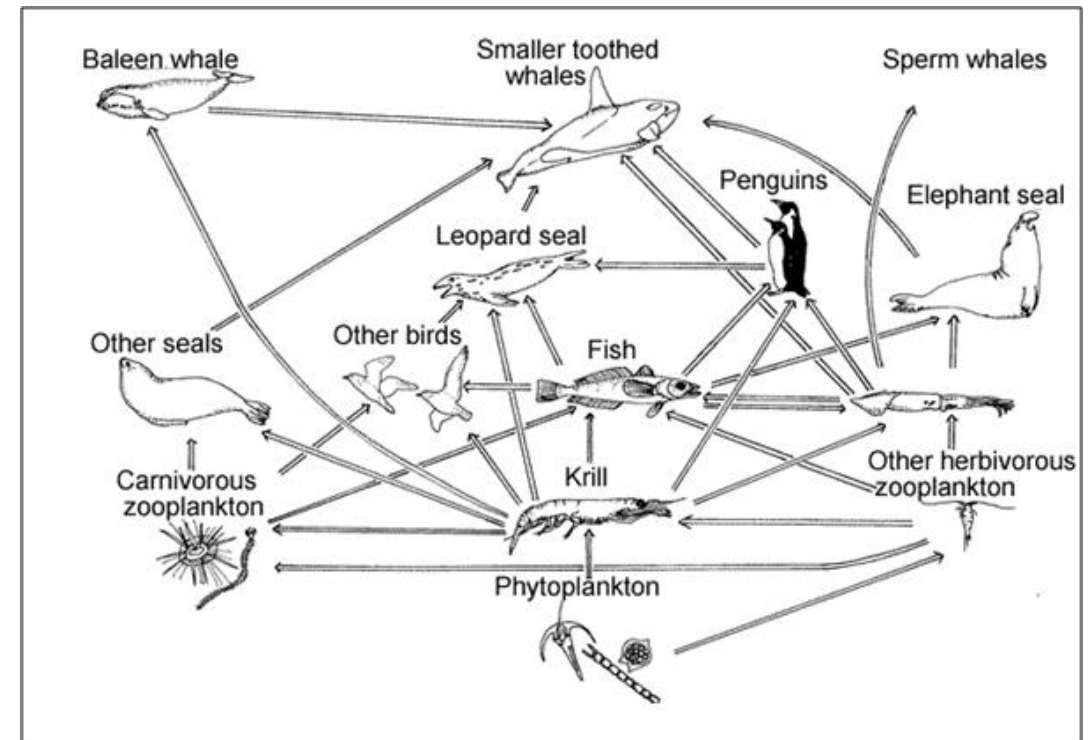
- What is ecosystem modelling and why use it?
- What is Ecopath with Ecosim?
- Where can I find more information?

Why use ecosystem modelling?

- The ‘wicked problem’ of ecosystem management
 - Ecological, social, and economic interactions
 - Numerous interactions, feedback loops and dependencies
- Historical management strategies can lead to problems
 - Single species or single threat is too narrow
 - Poor outcomes in fisheries, conservation, invasive species management and/or biocontrol
- Recent advances in ecological theory, computing power, and model development means ecosystem modelling approaches are in high demand
 - Data limitations and uncertainty can be addressed
- Three common objectives:
 - Describe and understand the ecosystem
 - Understand historical or future scenarios
 - Decide on management actions

What is ecosystem modelling?

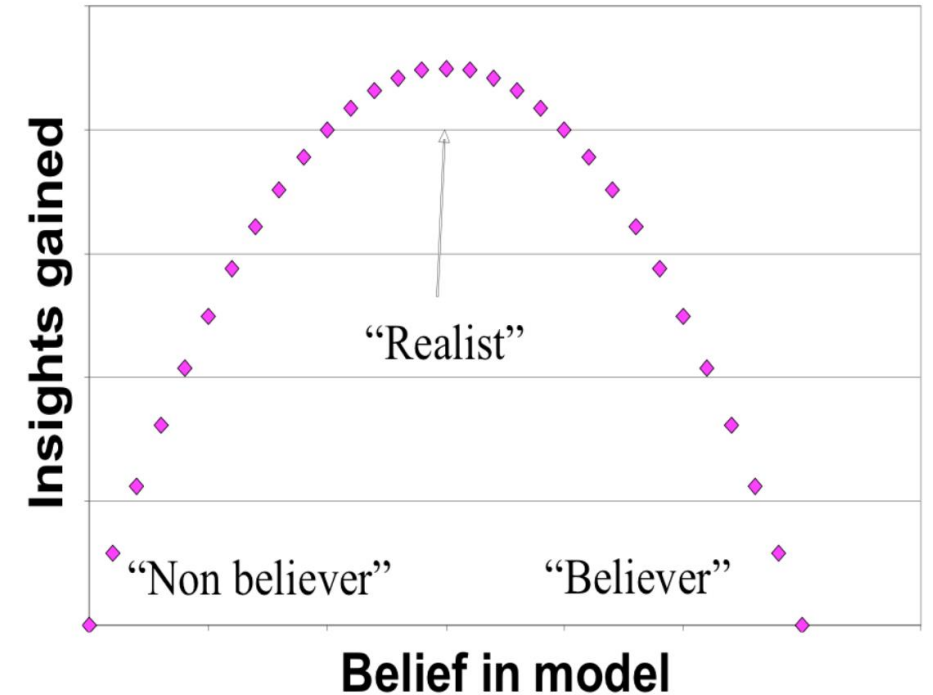
- Simplified holistic network representation of the ecosystem
- Incorporate ecosystem components
 - E.g., populations, species, functional groups
- Incorporate ecosystem processes
 - E.g. prey-predator interactions, perturbations, dispersal
- Assess or support ecosystem management
 - E.g. fisheries management



What do we know about the dynamics in the marine environment?

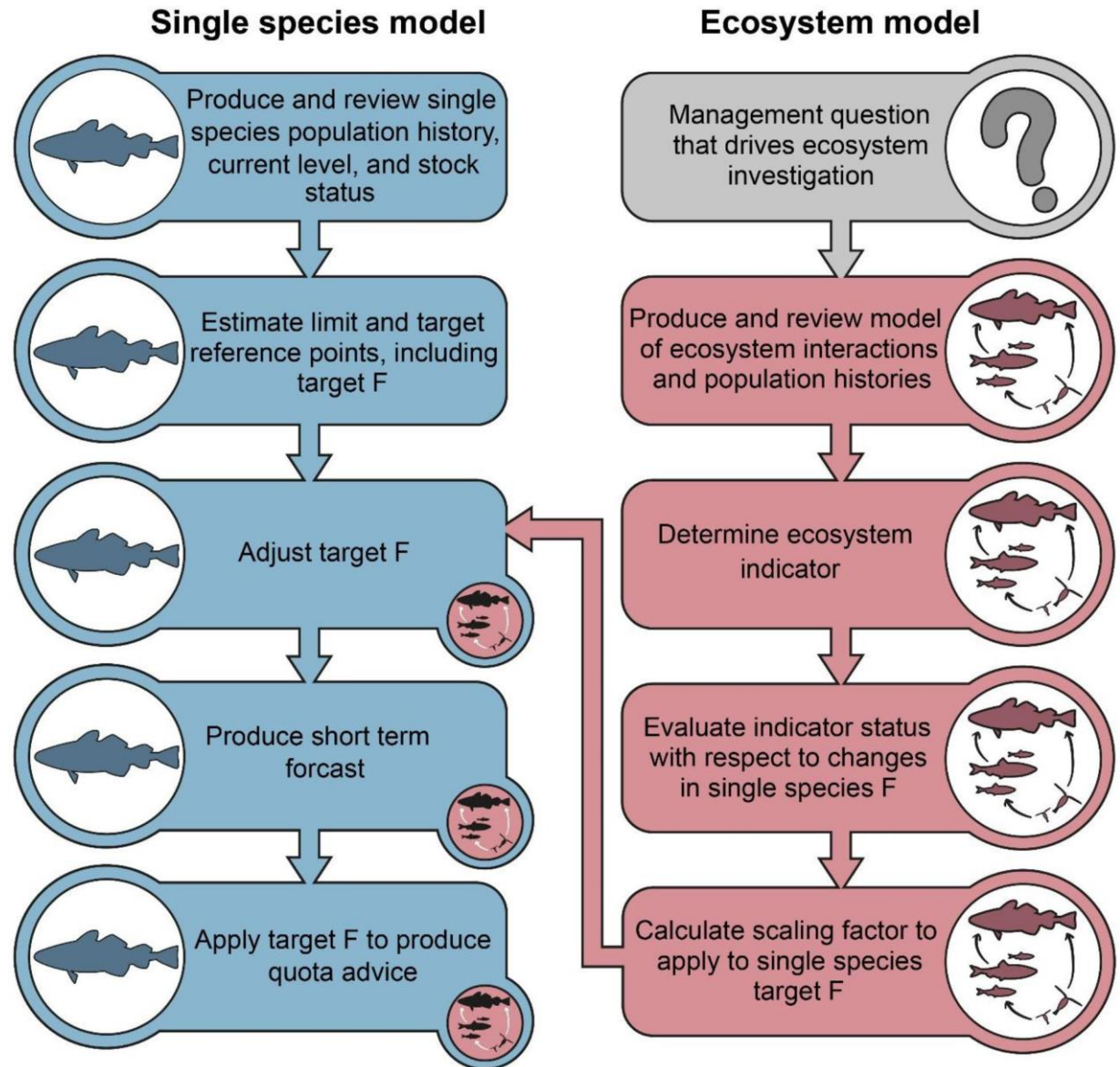
- Synthesizing food-web information and environmental change
 - What is the ecosystem like?
 - Ecosystem functioning and structure
 - Uncertainty comes from parameters and structure of model

Aydin's Modelling Yield Curve



What do we know about the dynamics in the marine environment?

- Synthesizing food-web information and environmental change in a fishery system
 - What is the ecosystem like?
 - Useful for a fishery system
 - Match needed between model qualities and structure to the management problem or application
 - Decision-support tool
 - What are outcomes of different policy options?
 - What are the trade-offs that can arise from ecological processes and management interventions?
 - Develop strategic and tactical resource management advice



Frequency of use	Always	Objective of model development			Spatial and temporal patterns		Ecosystem component				Ecosystem processes			
	Often	Describe and understand current ecosystem	Forecast/hindcast scenarios	Decide on management actions	Incorporate multiple spatial scales	Temporally dynamic	Population (size, age) structure	Individual species	Aggregates/ groups of taxa	Ecosystem condition/state	Species interactions	Dispersal	Single-node perturbations	Whole-of-ecosystem perturbations
Sometimes	Rarely													
Ecosystem modelling approach														
Conceptual model	Often	Often	Rarely	Rarely	Rarely	Sometimes	Often	Often	Rarely	Often	Rarely	Rarely	Sometimes	Sometimes
Loop analysis	Often	Rarely	Sometimes	Rarely	Rarely	Sometimes	Rarely	Often	Rarely	Often	Always	Rarely	Often	Often
Fuzzy cognitive map	Often	Sometimes	Sometimes	Rarely	Rarely	Sometimes	Often	Often	Rarely	Often	Rarely	Often	Often	Often
Bayesian belief network	Often	Often	Often	Sometimes	Rarely	Often	Often	Often	Rarely	Often	Rarely	Often	Often	Often
Graph-theoretic network analysis	Often	Often	Sometimes	Rarely	Rarely	Sometimes	Often	Often	Rarely	Often	Always	Rarely	Often	Often
Co-occurrence analysis	Often	Rarely	Sometimes	Always	Always	Rarely	Often	Often	Rarely	Sometimes	Rarely	Often	Often	Often
Structural equation model	Often	Often	Sometimes	Rarely	Rarely	Often	Often	Often	Always	Always	Rarely	Always	Always	Rarely
Multi-species population dynamic model	Rarely	Often	Often	Often	Often	Sometimes	Always	Often	Rarely	Often	Often	Often	Often	Rarely
State-transition model	Rarely	Often	Often	Often	Often	Always	Rarely	Often	Always	Always	Rarely	Often	Always	Always
Mass-balance models	Often	Always	Rarely	Sometimes	Sometimes	Often	Often	Often	Always	Always	Sometimes	Always	Always	Often
Agent-based/ individual-based model	Often	Always	Sometimes	Always	Always	Often	Always	Sometimes	Sometimes	Often	Always	Always	Always	Sometimes
Models of intermediate complexity (MICE)	Often	Always	Often	Often	Often	Often	Always	Always	Rarely	Always	Often	Always	Always	Often
Ensemble ecosystem model*	Often	Always	Often	Often	Often	Sometimes	Always	Always	Sometimes	Always	Sometimes	Always	Always	Often
End-to-end ecosystem model	Always	Always	Often	Always	Always	Often	Often	Always	Always	Always	Often	Always	Always	Always

Increasing data/resources/knowledge required

- Choice of model should depend on need (question, role) and data availability (including accuracy)
 - Note that uptake is not always data related (Craig & Link 2023)
- Requirements can result in using multiple types of models to support aim

Frequency of use	Always	Objective of model development			Spatial and temporal patterns		Ecosystem component				Ecosystem processes			
	Often	Describe and understand current ecosystem	Forecast/hindcast scenarios	Decide on management actions	Incorporate multiple spatial scales	Temporally dynamic	Population (size, age) structure	Individual species	Aggregates/ groups of taxa	Ecosystem condition/state	Species interactions	Dispersal	Single-node perturbations	Whole-of-ecosystem perturbations
Sometimes	Rarely													
Ecosystem modelling approach														
Conceptual model	Often	Often	Rarely	Rarely	Rarely	Often	Often	Often	Rarely	Often	Rarely	Rarely	Often	Often
Loop analysis	Often	Rarely	Often	Rarely	Rarely	Often	Rarely	Often	Rarely	Often	Always	Rarely	Often	Often
Fuzzy cognitive map	Often	Often	Often	Rarely	Rarely	Often	Often	Often	Rarely	Often	Rarely	Often	Often	Often
Bayesian belief network	Often	Rarely	Often	Rarely	Often	Often	Often	Often	Rarely	Often	Rarely	Often	Often	Often
Graph-theoretic network analysis	Often	Rarely	Often	Rarely	Often	Often	Often	Often	Rarely	Often	Always	Rarely	Often	Often
Co-occurrence analysis	Often	Rarely	Often	Rarely	Always	Often	Often	Often	Rarely	Often	Rarely	Often	Often	Often
Structural equation model	Often	Rarely	Often	Rarely	Often	Often	Often	Often	Rarely	Often	Always	Rarely	Often	Rarely
Multi-species population dynamic model	Rarely	Often	Often	Often	Often	Often	Often	Often	Rarely	Often	Often	Often	Often	Rarely
State-transition model	Rarely	Often	Often	Often	Often	Often	Rarely	Often	Often	Often	Rarely	Often	Often	Always
Mass-balance models	Often	Always	Rarely	Often	Often	Often	Often	Often	Often	Often	Often	Often	Always	Often
Agent-based/ individual-based model	Often	Always	Often	Often	Often	Often	Often	Often	Often	Often	Often	Often	Always	Often
Models of intermediate complexity (MICE)	Often	Always	Often	Often	Often	Often	Often	Often	Rarely	Often	Often	Often	Always	Often
Ensemble ecosystem model*	Often	Always	Often	Often	Often	Often	Often	Often	Often	Often	Often	Often	Always	Often
End-to-end ecosystem model	Always	Always	Often	Often	Often	Often	Often	Often	Often	Often	Often	Often	Always	Always

Increasing data/resources/knowledge required

- Choice of model should depend on need (question, role) and data availability (including accuracy)
 - Note that uptake is not always data related (Craig & Link 2023)
- Requirements can result in using multiple types of models to support aim

Ecopath with Ecosim (EwE)

- Widely used model framework, developed for fisheries management
 - Recognised as 1 of the 10 biggest scientific breakthroughs in NOAA
- Flexible
 - Ecopath – static mass-balance model
 - Ecosim – time-dynamic simulation
 - Ecospace – spatial and temporal dynamic solution
- Capabilities
 - Address ecological questions
 - Evaluate ecosystem effects of environmental change and fishing
 - Explore management policy options, MPA placement, etc.
 - Predict movement and accumulation of contaminants and tracers
 - ... new ways are constantly being developed



EwE – easily done, hard to get right

- Many considerations (not a comprehensive list)
 - What is the aim of the model?
 - What components of the EwE framework do you need?
 - What is the conceptual model and how does it align with the aim?
 - What is the area of interest?
 - Should groups represent life stages, species, functional groups?
 - What time period is used as the base?
 - What is known about the fisheries in the area?
 - If you are going to use Ecosim, what time period will you use?
 - Are you using historical data or extrapolating into the future?
 - What forcings do you want to include and what are their potential effects?
 - What is the data availability for the model?
 - Does this influence the conceptual model design?
 - Is there expert knowledge available that can aid?

What components to include

- Specific species of interest may require higher resolution
 - Commercial or conservation interest
- Data availability may limit complexity of model
 - Species get grouped in functional groups
 - What data will you use?
- Common ecological knowledge can aid
 - Especially in lower trophic-level groups such as zooplankton or benthic fauna
 - Can include different life stages
- What time period are you trying to model?

Group	Functional group	Example species
10	Small demersal fishes	Marginate snailfish (<i>Careproctus aureomarginatus</i>), Crested spiny plunderfish (<i>Harpagifer palliolatus</i>), Letholycus microphthalmus, Magellan plunderfish (<i>Harpagifer bispinis</i>), Sculpin (<i>Bathylutichthys taranetzi</i>), Phucocoetes latitans, Small-spine snailfish (<i>Careproctus aculeolatus</i>), <i>Oidiphorus brevis</i> , Snailfish (<i>Agonopsis chilensis</i>), <i>Thysanopsetta naresi</i> , Patagonian moray cod (<i>Muraenolepis orangiensis</i>), <i>Lycodon malvinensis</i> , Fathead (<i>Cottunculus granulatus</i>), Dwarf codling (<i>Austrophycis marginata</i>), Cusk eel (<i>Cataetyx messieri</i>), <i>Maynea puncta</i> , <i>Galaxias platei</i> , <i>Psychrolutes marmoratus</i>
11	Large demersal fishes	<i>Iluocoetes fimbriatus</i> , Frogmouth (<i>Cottoperca trigloides</i>), <i>Crossostomus fasciatus</i> , Pike icefish (<i>Champscephalus esox</i>), Prickly flounder (<i>Achiropsetta tricholepis</i>), Brazilian flounder (<i>Paralichthys brasiliensis</i>), Patagonian redfish (<i>Sebastes oculatus</i>), Southwest Atlantic butterflyfish (<i>Stromateus brasiliensis</i>), <i>Xystreureys rasile</i> , Red cod (<i>Salilota australis</i>), Slender escolar (<i>Paradiplospinus gracilis</i>), Hagfish (<i>Myxine knappi</i>), Antarctic armless flounder (<i>Mancopsetta maculata</i>), Pouched lamprey (<i>Geotria australis</i>), eelpout (<i>Austrolycus depressiceps</i>), Finless flounder (<i>Mancopsetta milfordi</i>), Smooth oreo (<i>Pseudocyttus maculatus</i>), Plownose chimeara (<i>Callorhynchus callorhynchus</i>), Bigeye grenadier (<i>Macrourus holotrachys</i>), Hagfish (<i>Myxine fernholmi</i>), Southern seadevil (<i>Ceratias tentaculatus</i>), Patagonian blennie (<i>Eleginops maclovinus</i>), Pink cusk-eel (<i>Genypterus blacodes</i>)
12	Myctophidae	Rhombic lanternfish (<i>Krefflichthys anderssoni</i>), Fraser's lanternfish (<i>Gymnoscopelus fraseri</i>), rakery beaconlamp (<i>Lampanyctus macdonaldi</i>), Nichol's lanternfish (<i>Gymnoscopelus nicholsi</i>), lanternfish (<i>Gymnoscopelus opisthopterus</i>)
13	Deep pelagic fishes	Half-naked hatchetfish (<i>Argyropelecus hemigymnus</i>), common fangtooth (<i>Anoplogaster cornuta</i>), ribbon barracudina (<i>Arctozenus risso</i>), viperfish (<i>Chaudiodus sloani</i>), Bathylagidae, Alepocephalidae, blue antimora (<i>Antimora rostrata</i>), slender codling (<i>Halargyreus johnsonii</i>), Patagonian codling (<i>Lepidion ensiferus</i>), <i>Coryphaenoides armatus</i> , Antarctic scolar (<i>Paradiplospinus antarcticus</i>)
14	Rock cods	<i>Patagonotothen cornucola</i> , <i>P. wiltoni</i> , <i>P. brevicauda brevicauda</i> , <i>P. guntheri</i> , <i>P. sima</i> , <i>P. tessellata</i> , <i>P. Magellanica</i>
15	Southern blue whiting	<i>Micromesistius australis australis</i>
16	Patagonian toothfish	<i>Dissostichus eleginoides</i>
17	Hoki	<i>Macruronus magellanicus</i>
18	Southern hake	<i>Merluccius australis</i>
19	Common hake	<i>Merluccius hubbsi</i>
20	Epipelagic fishes	Falkland sprat (<i>Sprattus fuegensis</i>), southern driftfish (<i>Icichthys australis</i>), silverside (<i>Odontesthes nigricans</i>), slender tuna (<i>Allothunnus fallai</i>)
21	Argentine squid	<i>Illex argentinus</i>
22	Patagonian squid ASC	<i>Doryteuthis gahi</i> Autumn Spawning Cohort
23	Patagonian squid SSC	<i>Doryteuthis gahi</i> Spring Spawning Cohort

What data is required

- At a minimum, three from the combination of
 - Biomass
 - Production-biomass ratio (P/B)
 - Consumption-biomass ratio (Q/B)
 - Ecotrophic efficiency (EE)
- Ideally the model estimates EE, but without biomass estimates the user supplies this
- Initial estimates can come from survey reports, scientific studies, other models, best-practise advise, etc.
- Average for functional groups? Or are specific species better studied?

Functional group	B (t km ⁻²)	P/B (year ⁻¹)	Q/B (year ⁻¹)	EE
Baleen whales	2.630E-08	1.57	6.30	
Toothed whales and dolphins	0.020	2.03	8.10	
Pinnipeds	0.011	0.18	26.73	
Other penguins	0.006	0.53	46.68	
Gentoo penguin	0.003	0.53	46.68	
Shorebirds	0.001	1.15	73.59	
Seabirds	0.001	0.19	117.45	
Skates	0.061	0.40	4.10	
Sharkes		0.39	6.77	0.10
Small demersal fishes		0.65	4.52	0.20
Large demersal fishes		0.29	3.09	0.10
Myctophidae		1.11	9.33	0.50
Deep pelagic fishes		1.29	4.17	0.50
Rock cod	3.418	0.43	1.73	
Southern blue whiting	1.337	5.30	21.38	
Toothfish	0.109	0.34	1.37	
Hoki	1.569	0.17	0.67	
Southern hake	0.069	0.65	2.60	
Common hake	4.495	0.65	2.60	
Epipelagic fishes		1.00	7.06	0.80
Argentine squid		5.76	18.85	0.80
Patagonian squid ASC	0.112	5.76	18.84	
Patagonian squid SSC	0.180	5.74	18.56	
Small other cephalopods		5.76	18.85	0.80
Large other cephalopods		4.61	18.42	0.80
Small benthic fauna		2.80	7.60	0.80
Large benthic fauna		0.98	2.30	0.50
Predatory gelatinous zooplankton		3.80	18.70	0.50
Susp. gelatinous zooplankton		3.80	18.70	0.50
Krill		11.30	85.60	0.90
Lobster krill		11.30	85.60	0.90
<i>Themisto gaudichaudii</i>		11.30	85.60	0.90
Omni/carnivorous zooplankton		11.30	85.60	0.90
Grazing/susp. Zooplankton		26.10	80.80	0.90
Phytoplankton	212.00	78.00		0.50
Discards & Carrion	1.00			
Detritus	1.00			

What data is required

- Dietary matrix representing (annual) prey-predator interactions
- One option to include migration (import)
- Estimates ideally based on weight (%)
 - Studies more often use frequency of occurrence (%) or numerical content (%)
 - Identify trophic links, consider uncertainty
 - Average for functional groups? Or are specific species better studied?
- Needs to add up to 1 for each column

Prey \ predator	Baleen whales	Toothed whales and dolphins	Pinnipeds
Baleen whales	0	0	0
Toothed whales and dolphins	0	0	0
Pinnipeds	0	0	0
Other penguins	0	0	0.001
Gentoo penguin	0	0	0.001
Shorebirds	0	0	0
Seabirds	0	0	0
Skates	0	0	0
Sharks	0	0	0
Small demersal fish	0	0.049	0.13
Large demersal fish	0	0.019	0.028
Myctophidae	0	0.043	0
Meso-bathypelagic fish	0	0.057	0
Rock cod	0	0	0
Southern blue whiting	0	0	0
Toothfish	0	0.01	0
Hoki	0	0	0
Southern hake	0	0	0.005
Common hake	0	0	0.005
Pelagic fish	0	0.137	0.27
Argentine squid	0	0.034	0
Patagonian squid ASC	0	0.049	0.1
Patagonian squid SSC	0	0.049	0.17
Small other cephalopods	0	0.03975	0.0375
Large other cephalopods	0	0.01325	0.0125
Small benthic fauna	0	0.08	0.05
Large benthic fauna	0	0.05	0.07
Predatory gelatinous zooplankton	0	0	0
Susp. gelatinous zooplankton	0	0	0
Krill	0.143	0.14	0
Lobster krill	0.243	0.159	0.12
Themisto gaudichaudii	0.171	0.071	0
Omni/carnivorous zooplankton	0.072	0	0
Grazing/susp. zooplankton	0.071	0	0
Phytoplankton	0	0	0
Detritus	0	0	0
Import	0.3	0	0

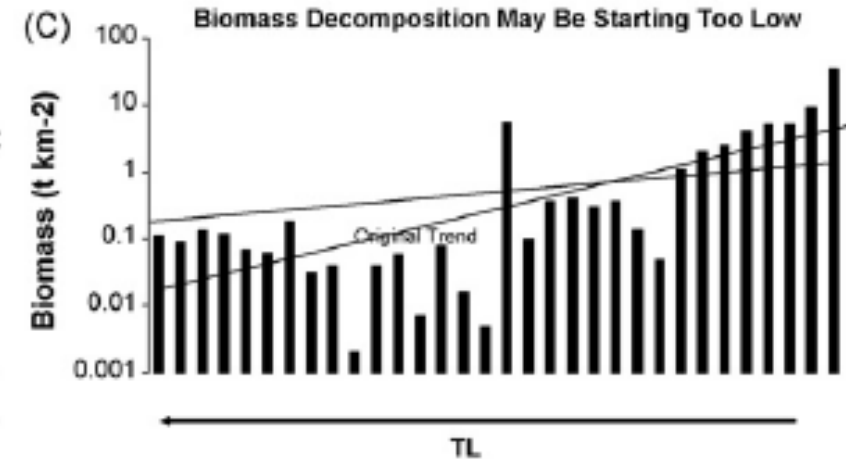
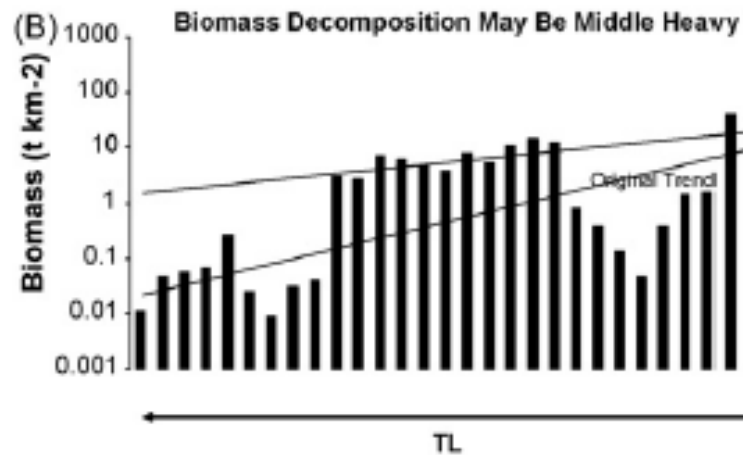
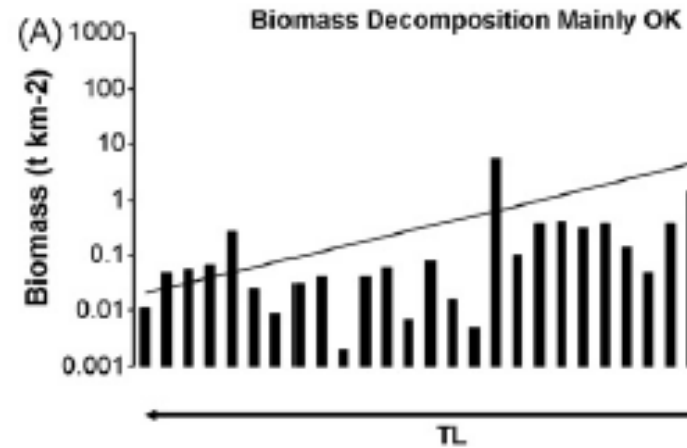
More considerations

- How to represent fisheries?
 - By fleet? By species targeted?
 - Include landings and discards and discard fate
 - Note that an economic component can be incorporated here in the model
- While can be kept to zero, depending on knowledge, you can include Other production:
 - What is known about immigration and emigration? (the other migration option)
 - What is known about the biomass accumulation?

Running Ecopath

- Very likely initial estimates are not mass conserved
 - Don't panic
- Ecopath provides warning for
 - $EE > 1$
 - Dietary matrix issues
- Now the iterative process begin
- Follow available advice (Link 2010, Ainsworth & Walters 2010; Heymans et al. 2016)
 - Address issues with outliers in Biomass, P/B and Q/B (PREBAL, Link 2010)
 - Consider issues in dietary matrix
 - In all, take into account uncertainty – first point to work on
 - Do issues arise from groups that should be split or combined?

PREBAL checks



Running Ecopath

- Very likely initial estimates are not mass conserved
 - Don't panic
- Ecopath provides warning for
 - $EE > 1$
 - Dietary matrix issues
- Now the iterative process begin
- Follow available advice (Link 2010, Ainsworth & Walters 2010; Heymans et al. 2016)
 - Address issues with outliers in Biomass, P/B and Q/B (PREBAL, Link 2010)
 - Consider issues in dietary matrix
 - In all, take into account uncertainty – first point to work on
 - Do issues arise from groups that should be split or combined?

Balanced model

- Inspect balanced model
 - Does it make sense?
- Ecopath can provide further information on ecosystem structure
 - Dominant energy flow
 - Keystone species
 - Etc.
- Provides basis for Ecosim and Ecospace

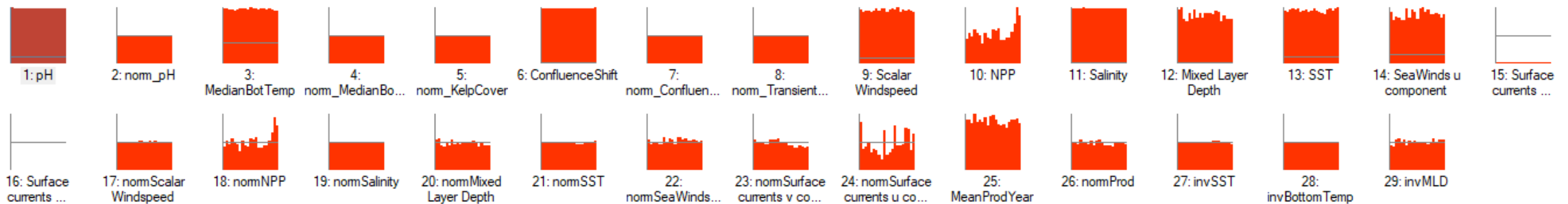
Group name	TL	B	P/B	Q/B	EE	
Baleen whales		3.470	2.630E-08	0.152	6.298	0.000
Toothed whales and dolphins		3.996	0.020	0.384	8.101	0.000
Pinnipeds		4.317	0.011	0.177	26.733	0.001
Other penguins		3.663	0.006	0.527	46.684	0.093
Gentoo penguin		4.121	0.003	0.527	46.684	0.170
Shorebirds		3.676	0.001	0.190	73.590	0.000
Seabirds		4.141	0.001	0.330	117.453	0.000
Skates		3.899	0.800	0.300	4.277	0.888
Sharks		4.176	0.003	0.300	7.020	0.050
Small demersal fishes		3.468	5.038	2.420	9.670	0.400
Large demersal fishes		4.267	1.182	0.873	3.491	0.200
Myctophidae		3.547	9.452	1.755	7.020	0.700
Deep pelagic fishes		3.756	10.923	0.965	3.862	0.500
Rock cod		3.644	3.418	1.000	2.900	0.957
Southern blue whiting		3.788	1.337	0.625	2.500	0.523
Toothfish		4.025	0.350	0.350	1.400	0.662
Hoki		4.339	1.569	0.525	2.100	0.194
Southern hake		4.472	0.069	0.550	1.700	0.330
Common hake		4.389	4.495	0.450	1.800	0.020
Epipelagic fishes		3.563	1.427	1.454	5.818	0.700
Argentine squid		4.034	0.106	5.764	18.850	0.700
Patagonian squid ASC		3.721	0.112	13.000	18.557	0.949
Patagonian squid SSC		3.809	0.180	8.500	19.136	0.978
Small other cephalopods		3.867	2.033	5.764	18.850	0.700
Large other cephalopods		4.542	0.001	4.605	18.418	0.700
Small benthic fauna		2.000	163.337	2.800	15.200	0.700
Large benthic fauna		2.300	57.113	2.800	15.200	0.500
Predatory gelatinous zooplankton		3.474	3.549	3.800	18.700	0.500
Susp. gelatinous zooplankton		2.000	83.754	3.800	18.700	0.500
Krill		2.000	32.052	11.300	85.600	0.850
Lobster krill		2.152	26.216	11.300	85.600	0.850
<i>Themisto gaudichaudii</i>		3.282	14.645	11.300	64.200	0.850
Omni/carnivorous zooplankton		3.012	29.084	11.300	64.200	0.850
Grazing/susp. zooplankton		2.000	47.275	26.100	80.800	0.850
Phytoplankton		1.000	212.000	78.000		0.500
Discards & carrion		1.000	1.000			
Detritus		1.000	1.000			0.00

Ecopath with Ecosim

- Ecopath can be run for a specified time period
- When life stages are incorporated, egg production scenarios are an option
- Various options for fishing practices (effort, mortality, size dynamics, catchability, prices)
- Forcings can be applied
 - Affect prey-predator interactions, foraging or mortality (forcing function or environmental responses)
 - Mediating forcings also possible
 - Catch data is a forcing

Ecopath with Ecosim

- Hind- or forecasting
- Forcings can be applied
 - Affect prey-predator interactions, foraging or mortality (forcing function or environmental responses)
 - Mediating forcings also possible
 - Catch data is a forcing



Ecopath with Ecosim

- Forcings can be applied
 - Which forcings to apply?
 - What will the forcing affect?
 - Prey-predator interactions, foraging or mortality (forcing function or environmental responses)
 - Prey-predator interactions can be affected via effects in search rates, vulnerability, or arena area
 - Mediating forcings also possible to include
- Catch data is a forcing (automatically when data are loaded)

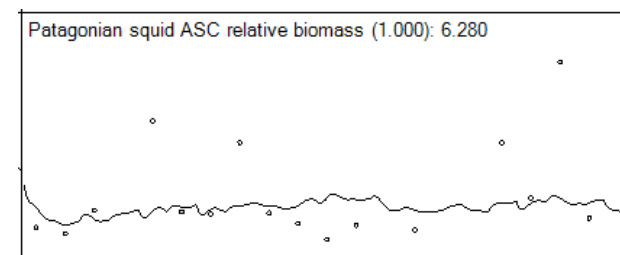
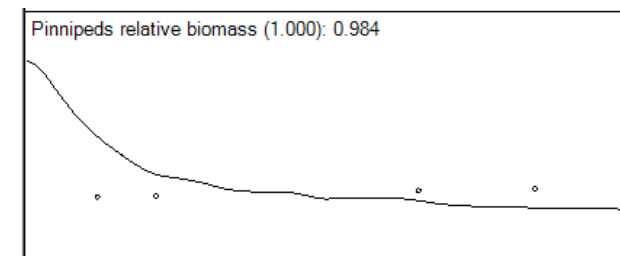
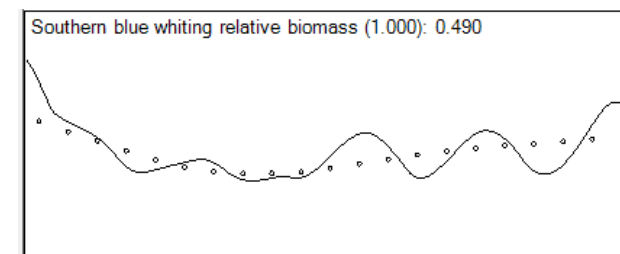
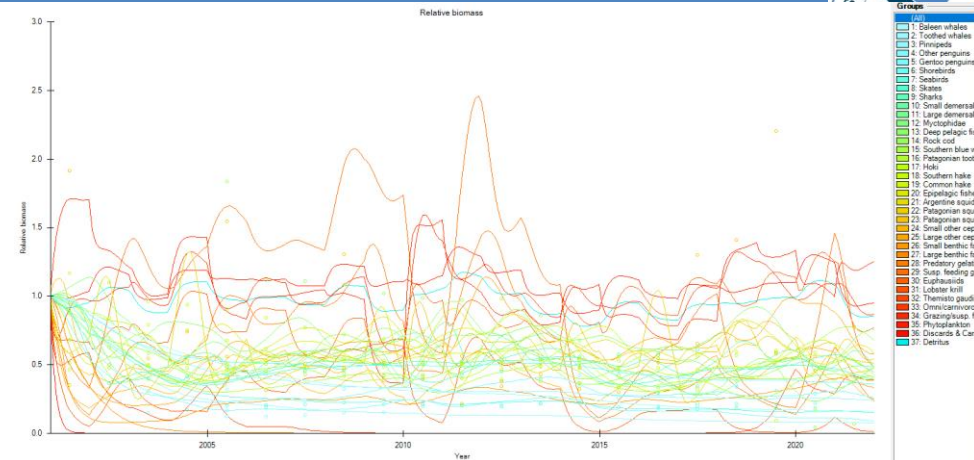
The screenshot displays the Ecopath with Ecosim interface. At the top, a prey-predator matrix is visible, with columns representing prey groups (1-6) and rows representing predator groups (1-37). The matrix contains numerical values indicating the strength of interactions between different groups.

Below the matrix, a dialog box is open, titled 'Source group '3: Pinnipeds' Target group '11: Large demersal fishes''. This dialog allows users to apply various forcing functions to the target group. The 'Available functions' list includes environmental and biological parameters such as pH, salinity, and sea surface temperature. The 'Applied functions' section shows that function '23: nomSurface currents ...' is selected, with the modifier 'Arena area (A)'.

At the bottom of the dialog, there are radio buttons to specify the multiplier to be applied: 'Search rate (a)', 'Vulnerability (v)', 'Arena area (A)', and 'Vul (v) and area (A)'. The 'Search rate (a)' option is currently selected.

Ecopath with Ecosim

- Run future scenarios or historical scenarios
- Historical scenarios
 - Model calibration – need reference (biomass) time series
 - Ideally models are calibrated prior to future scenario explorations
 - Understanding past changes
- Future scenarios
 - Exploring policy options
 - Investigating future environmental change
- What can be included depends on interest and data availability



Where can I find more information?

- EwE website: <https://ecopath.org/>
 - Download software
 - List service can be found here, FAQ, and other options for help
- Graduate course (**Fish501**) is freely available, created by the experts developing, supporting, and maintaining the EwE software (link in word doc)
 - Follow course at own pace, break it up as you follow along with your model
 - Lectures available on Youtube <https://www.youtube.com/@EcopathwithEcosim>
 - Course (lectures, tutorials, assignments) available on course website <https://sites.google.com/view/fish501-2021/home>
 - Take the time to study
 - Plenty of peer-reviewed articles
 - Many Ecopath models published (EcoBase) <https://ecobase.ecopath.org/#discoverytools>
- Several papers are available providing best-practice advice
 - Link 2010 - PREBAL
 - Ainsworth & Walters 2010 – 10 common mistakes
 - Heymans et al. 2016 – best practice advice
 - EwE user guide

These references will be shared after the workshop

Thank you for listening!

Are there any questions?

